Safe Flight 21

Initial Report of the Safe Flight 21 Cost Benefit Subgroup Volume 1

May 2000

Acknowledgements

This report was prepared under the sponsorship of the Safe Flight 21 Steering Committee, the Federal Aviation Administration (FAA) Directorates AND-500 and ASD-400. The Safe Flight 21 Cost Benefit Subgroup, which was formed in the summer of 1999, conducted the analysis contained in this report as the initial phase of activity leading to a Limited Deployment (LD) decision. We gratefully acknowledge the organizations and individuals for their major contributions to the analysis and to the development of this preliminary report. See Volume 1, Appendix B for list of contributors.

EXECUTIVE SUMMARY

This initial report of the Safe Flight 21 Cost Benefit Subgroup summarizes the analysis conducted since the team was formed in September 1999. This phase of work provided the basis for the Safe Flight 21 FY02 budget formulation, and an initial rough order estimate of the benefits that could accrue from selected Safe Fight 21 Enhancements. Volume 1 of this report contains the summary of findings, and Volume 2 contains detailed information and supporting data.

This phase of analysis concentrated on cost and benefits for Limited Deployment (LD) of the Safe Flight 21 Enhancements in Ohio River Valley (ORV) and Alaska (Capstone) during the ten-year period beginning in FY02. Costs incurred prior to FY02 were not included in the analysis.

Estimates for ORV included cost for development and implementation of technology, procedures, ground infrastructure, and industry avionics under various datalink scenarios. The estimates covered both single and dual link configurations. The FAA capital costs for single and dual link scenarios totaled $49.6M and $50.1M, respectively. The industry aircraft avionics costs to equip 444 cargo aircraft for single 1090 datalink or dual 1090/Universal Access Transceiver (UAT) datalink were $95.4M and $122.7M, respectively. Costs for other datalink combinations are included in the detailed sections of this report.

The Alaska Capstone cost estimates included the introduction of over 200 Automatic Dependent Surveillance-Broadcast (ADS-B) ground stations enabling statewide use of UAT datalink, and additional Automated Weather Observation System (AWOS) and Local Area Augmentation Systems (LAAS) providing new capabilities at FAA locations in Alaska improving aviation safety and efficiency. The FAA capital costs total $85.1M. The operations costs are estimated at $87.9M, primarily for leased telecommunications. Industry costs to voluntarily equip 3,850 aircraft were estimated to be $106M.

The team reviewed the Safe Flight 21 Enhancements and developed a set of benefit outcome metrics to describe the operational benefits expected from implementation of Safe Flight capabilities. Benefit estimates for this phase of analysis included six of the nine enhancements and concentrated on the major metrics of safety and efficiency. The remaining metrics and enhancements will be addressed in the next phase of analysis. The internal industry business case is expected to yield significant benefits, but is not included in this report.

Benefit estimates for LD during the ten-year period totaled $574M. Cost-Effective Controlled-Flight-Into-Terrain (CFIT) avoidance provided the majority of benefits resulting in an estimated $297M saving from avoided CFIT accidents in Alaska. In ORV, the combined effect of Improved Terminal Operations and Enhanced Surface Surveillance for the Controller is expected to reduce inter-arrival and departure spacing in the terminal area. This results in an estimated $186M savings in aircraft direct operating costs. Weather Information in the Cockpit, Enhanced See and Avoid, and Enhance Surface Surveillance for both the Pilot and Controller accounted for the remaining $91M in benefits, primarily from a reduction in accidents.

This report provides a good initial estimate of the cost to implement the Safe Flight 21 Enhancements on an operational basis in ORV and Alaska. Accuracy of these estimates will improve in the next phase of analysis. The benefits as quantified in this report are incomplete, but should increase substantially with the addition of an industry business case analysis and additional metrics. The investment appears to be cost beneficial and provides significant advantage in reducing risks associated with subsequent implementation of ADS-B on a NAS-wide basis.

TABLE OF CONTENTS

VOLUME 1

VOLUME 2

1.0 INTRODUCTION

1.1 Organization

This report compiles the results of the Safe Flight 21 Cost Benefit Subgroup Phase 1 analysis, methodologies, models and tools, and is organized as follows.

Volume 1 provides the results of the Safe Flight 21 Phase 1 cost benefit analysis. It is divided into two parts: a high-level report of findings followed by Appendices A and B, which contain the fully annotated version of the briefing presented to the Safe Flight 21 Steering Committee in March 2000, and the list of contributors.

Volume 2 (Appendices C through G) contains in-depth documentation of the Phase 1 data review, assumptions, and results used to complete the Rough-Order-of-Magnitude (ROM) cost and benefit estimates. Volume 2 also provides a summary of the Safe Flight 21 Master Plan, the Safe Flight 21 Benefit Outcome Metrics, and a description of the models and tools.

1.2 Background

The Safe Flight 21 program is a joint government/industry initiative designed to demonstrate and validate, in a real-world environment, the capabilities of advanced surveillance systems and air traffic procedures associated with Free Flight, using the Global Positioning System (GPS), Automatic Dependent Surveillance-Broadcast (ADS-B), Flight Information Services-Broadcast (FIS-B), and Traffic Information Services-Broadcast (TIS-B) as enabling technologies. Safe Flight 21 is a collaborative effort to deploy and evaluate the following nine Free Flight operational enhancements as outlined in the Safe Flight 21 Master Plan, dated February 2000.

1. Weather and Other Information In The Cockpit
2. Cost-Effective Controlled-Flight-Into-Terrain (CFIT) Avoidance
3. Improved Terminal Operations in Low Visibility
4. Enhanced See and Avoid
5. Enhanced En Route Air-to-Air Operations
6. Improved Surface Navigation for the Pilot
7. Enhanced Surface Surveillance for the Controller
8. ADS-B Surveillance in Non-Radar Airspace
9. ADS-B Separation Standards

The Safe Flight 21 Cost Benefit Subgroup, under this Phase I study, collaborated with the other Safe Flight 21 subgroups, FAA Systems Engineering, manufacturers, and the operators to obtain cost and benefits data and develop a cost benefit analysis.

1.3 Objective

The objective of this report is to document a ROM estimate of costs, benefits, and economic analysis of the Safe Flight 21 limited deployment (LD) as input to the FAA FY02 budget process. The report provides a general overview of the entire costing effort with a short synopsis for both the Ohio River Valley (ORV) and Alaska Capstone.

1.4 Scope of Analysis

The Phase I analysis provides information on the trade-off between the different levels of capability, architecture, and technology options explored within Safe Flight 21, and serves as the basis for recommendations to the Safe Flight 21 Steering Committee. Phase I focused on assessing the cost and benefits of the three candidate ADS-B/FIS-B links as they pertain to the nine operational enhancements under LD in the ORV and Alaska Capstone.

The scope of Phase I includes:

- ROM LD cost estimates used to support the Safe Flight 21 Capital Investment Plan (CIP) budget estimate for the SEOAT Analytic Team/Systems Engineering Operational Analysis Team (SAT/SEOAT).
- ROM LD and NAS-wide benefit estimates for selected Safe Flight 21 enhancements.
- Preliminary results of economic variables such as net present value (NPV) and benefit/cost (B/C) ratios based on the ROM LD cost and benefit estimates.

Also under Phase I, the team identified the steps for continuation in the next phase of analysis, and provided input for user briefings, technical program decisions, such as link technologies, and formulation of the FAA FY02-06 Facilities & Equipment (F&E) budget.

The initial phase of Research & Development (R&D) and prototyping activities prior to FY02 is not included in this analysis.

1.4.1 Ohio River Valley

Limited deployment in the ORV consists of single and multiple datalink scenarios with FAA ground and automation infrastructure at Memphis, Louisville, and Wilmington. The industry scope includes aircraft avionics for Airborne Express, UPS, and FedEx. Six datalink scenarios of single or dual equipage of the three candidate link technologies were evaluated.

- Mode Select (Mode S) Extended Squitter,
- Universal Access Transceiver (UAT), and
- VHF Data Link (VDL) Mode 4.

1.4.2 Alaska/Capstone

The scope of LD in Alaska consists of a single UAT datalink scenario for the entire state. The FAA infrastructure includes ground-broadcast stations, automation interfaces, and additional Local Area Augmentation System (LAAS) and Automated Weather Observation System (AWOS) installations for added capability. The team assumed that significant general aviation and air taxi aircraft would equip with the Capstone avionics package providing ADS-B, FIS-B, and Terrain Situational Awareness.

2.0 COSTS

2.1 Overview

The Life Cycle Cost Subteam developed F&E/Operations and Maintenance (O&M) ROM FAA and user (industry) cost estimates for LD in the ORV under various datalink scenarios, and for implementation of Alaska Capstone from 2002-2011. The cost subteam identified cost impacts to these estimates depending on single and dual link configurations. Facilities & equipment requirements from 2002-2006 were presented to the SAT/SEOAT for incorporation into the CIP. A summary of the results is presented in Volume 1, Appendix A. Detailed results are presented in the Safe Flight 21 LD Technical Baseline and Cost Briefing dated April 14, 2000, and included in Volume 2, Appendix C of this report.

The estimates will be refined as part of the Safe Flight 21 LD Investment Analysis planned for next year. During this time, the cost subteam will also develop a ROM estimate for NAS-wide implementation for presentation to the Safe Flight 21 Steering Committee.

2.1.1 Data Collection and Technical Baseline

The cost subteam collected data to define the technical baseline and cost estimating methodologies. Data collection activities included reviewing existing FAA and industry plans and documentation, accessing applicable databases, analyzing historical costs, and conducting interviews with representatives from organizations related to the Safe Flight 21 program. Such organizations included the Safe Flight 21 Program Office, Capstone Program Office, prime contractors and vendors, prospective installation sites, FAA Logistics Center, FAA Technical Center, and the FAA Training Academy. The data collection activities focused on the life cycle cost estimating methodologies for the various work breakdown structure (WBS) elements. Enhancement costs were allocated by government or industry and by life cycle phase where appropriate. The following WBS formats were used to organize costs.

Facilities and Equipment Costs

- System Equipment
  - Hardware/Software
  - System Engineering
  - Program Management
  - System Test and Evaluation
  - Data
- System Installation
  - Installation Design/Survey/Prep
  - Installation and Checkout
- Additional System Costs
  - Telecom/Utilities/Leases
  - Initial Maintenance
  - Initial Spares
  - Training
  - Support Facility
  - Support Equipment
  - Program Office Support
  - Engineering Change Orders

Operations and Maintenance Costs

- Annual Maintenance
  - Telecom/Utilities/Leases
  - Repairables/Consumables
  - Labor
    - Site Technician
    - Inventory Management
    - Repair
  - Training
  - Certification

The Safe Flight 21 technical baseline defines the programmatic requirements of implementing the operational enhancements in ORV and Alaska Capstone. The technical baseline outlines the hardware and software configuration of each enhancement, quantities and installation methods, maintenance concepts, and ground rules and assumptions. The cost subteam documented the technical baseline based on solicitation from both industry and government.

2.1.2 Cost Model Development

A robust and dynamic cost model was developed using the Automated Cost Estimating–Integrated Tool (ACE-IT). The cost model facilitates time-phasing costs on an annual basis by WBS element and summarizes costs by program phase. The cost model also provides the capability to conduct "what-if" exercises and sensitivity analyses. The estimate structure lends itself to the allocation of benefits and also facilitates the derivation of B/C ratios.

2.2 Limited Deployment - Ohio River Valley

2.2.1 Technical Baseline

Limited deployment in the ORV includes the on-going effort to develop and implement suitable avionics technology, pilot procedures for air-air surveillance, and a ground-based ADS-B system for air traffic control (ATC). The FAA procurement and implementation of surface and automation requirements will be completed by FY03. However, operational evaluations will continue through FY05 in the terminal areas that which support cargo aircraft operations at Memphis, Louisville, and Wilmington. The FAA costs also include avionics development, FIS-B development/automated weather, software changes, TIS-B development, NASA AMES simulation activities, Program Office support, and Regional/Tech Center support.

2.2.2 Basis of Estimate

The cost subteam used various methodologies to derive the ORV cost estimates. The cost subteam worked with Sensis Corporation to develop the terminal and enroute ground infrastructure costs; VNTSC, Sensis, and MITRE-CAASD provided automation interface costs. The cost subteam also worked with UPS to derive the vehicle ADS-B equipage costs. The AND-510 Program Manager provided a planning estimate for avionics development, FIS-B development/automated weather, software changes, and TIS-B development, and NASA AMES provided ROM costs for the simulation activities to test and monitor the performance of the new technologies. (See Table 2-1 below)

Table 2-1. Cost Results (Current Year $M)

ORV F&E	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	Total
Total Required Funding	$14.8	$11.4	$10.3	$9.7	$3.4	$49.6

ORV O&M	FY 2004	FY 2005	FY 2006	FY 2007	FY08-FY11	Total
O&M Costs	$0.2	$0.2	$0.9	$0.8	$3.5	$5.6

2.3 Limited Deployment – Alaska Capstone

2.3.1 Technical Baseline

Alaska Capstone will put in place the ADS-B ground infrastructure, over 201 ground stations, enabling statewide use of the UAT data link with ADS-B applications. In addition, airport vehicles will be equipped with ADS-B. The Capstone Program Office has worked with industry and general aviation pilots to equip 150 commercial and general aviation aircraft with avionics suites for operational evaluation activities in the Bethel region. The M-EARTS automation software in the Anchorage center also has been upgraded to accept ADS-B targets, fuse them with radar targets, and present a consolidated air traffic picture to the controllers. The Capstone program also is implementing AWOS systems to provide weather information to pilots who need to fly in instrument flight rules (IFR) conditions. Procedures also are being developed for Global Positioning System (GPS) precision approaches, and LAAS systems will be placed at high-traffic airports to replace instrument landing systems (ILSs) currently in place. At the same airport locations, the Capstone program is implementing multiprocessors (fusion servers) to fuse aircraft and vehicle ADS-B tracks with long-range radar data, enabling it to be sent to the controller displays, as well as being broadcast by the ground stations.

2.3.2 Basis of Estimate

The three main methodologies used to derive the Alaska costs were vendor quotes, Capstone Program Office engineering assessments, and analogies based on historical actuals. The cost subteam worked with UPS and the program office to develop the ADS-B ground-broadcast transceiver and vehicle ADS-B equipment costs. The cost subteam also worked with VNTSC to derive the multiprocessor equipment costs. Local area augmentation system inputs were provided by the Satellite/Navigation Investment Analysis Report (SAT/NAV IAR) and AWOS information was provided by the AWOS Program Office and FAA/ANI-700. Telecommunications costs were based on historical actuals. The Capstone Program Office provided data to help develop automation, program office support, and installation estimates. (See Table 2-2 below)

Table 2-2. Cost Results (Current Year $M)

Alaska F&E	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	Total
Total Required Funding	$21.1	$20.5	$21.1	$19.4	$3.1	$85.2

Alaska O&M	FY 2002	FY 2003	FY 2004	FY 2005	FY06-FY11	Total
O&M Costs	$1.0	$1.8	$4.4	$6.8	$73.9	$87.9

2.4 NAS-wide Implementation

A ROM life cycle cost estimate for NAS-wide implementation is underway and will be completed under the Phase 2 effort. The first step in the process is to define the scope of the estimate. The FAA quantities, locations, architecture, etc. have yet to be defined. Costs will be derived using knowledge gained in the LD estimate. A more defined maintenance concept will have to be developed to support an FAA NAS-wide infrastructure. The cost subteam also must develop a methodology to generate costs for potential aircraft equipage NAS-wide. Quantities, types of aircraft, and baseline configuration for modification will be identified with assistance from industry representatives. Range estimates will be provided along with risk analyses on high cost and high-risk WBS elements. The expected completion date for the NAS-wide estimate is December 2000.

2.5 Summary

The FAA and industry costs for LD are summarized in Table 2-3 below. Both the ORV and Alaska F&E totals exceed current CIP funding levels. If not fully funded, total benefits cannot be realized. Also, the ORV will be used as an ongoing test bed for risk mitigation/cost avoidance in preparation for Safe Flight 21 NAS-wide implementation. Insufficient funding will increase NAS-wide implementation costs and risk. The system quantities and annual cost by WBS element are shown in Volume 2, Appendix C.

Table 2-3. Safe Flight 21 Cost Summary (Current Year $M)

	F&E	O&M	Total
ORV	$49.6	$5.6	$55.2
Alaska	$85.1	$87.9	$173.0
Total FY02-11	**$134.8**	**$93.5**	**$228.2**

3.0 BENEFIT METRICS

The Safe Flight 21 Cost Benefit Subgroup began the Phase 1 analysis with a series of workshops to develop benefit metrics from the capabilities provided by each of the nine Safe Flight 21 enhancements. Each enhancement was considered relative to the impact it would have on pilots, controllers, or other special aspects of flight operations. These workshops resulted in a set of benefit outcome metrics that forms the basis of the benefit analysis. The outcome metrics is a working document and will be defined further or added to as the Safe Flight 21 program develops. Several of the benefit outcome metrics can be measured through data collection, such as aircraft flight time or longitudinal separation. Others metrics might be suited more for estimation through the use of simulation, surveys, or observations from participating aircrews in operational evaluations. Some of the benefit metrics are very difficult to quantify and may only be addressed qualitatively. The complete listing of benefit metrics is shown in Volume 2, Appendix F.

A subset of the benefit metrics was analyzed during the Phase 1 analysis. Information to establish a benefits baseline for the Phase 1 analysis was drawn from a variety of operational databases and information sources. For a full listing of data sources, refer to Volume 2, Appendix G.

4.0 BENEFITS

4.1 Scope

4.1.1 Enhancements

The team organized benefit metrics into three major areas - safety, efficiency, and FAA cost savings. Only safety and efficiency metrics were addressed in the Phase 1 analysis. Monetary benefits were estimated based on accident cost and hourly aircraft direct operating costs for fuel, crew, and maintenance.

The cost benefit team selected six of the nine Safe Flight 21 enhancements for the Phase 1 analysis as shown in Table 4-1 below. The selection criteria were based on two important factors: data availability and a high probability of finding substantial quantifiable benefits.

Table 4-1. Scope of Benefits Analysis

Enhancement	Safety	Efficiency
1) Flight Information Services – Broadcast (FIS-B)	✓	
2) Controlled Flight into Terrain (CFIT)	✓	
3) Low Visibility Terminal Operations (LVTO)		✓
4) Enhanced See and Avoid (ESA)	✓	
5) En Route Air-to-Air (ERA/A)		
6) Surface/Approach Operations (S/AO)	✓	✓
7) Airport Surface Display for Controller	✓	✓
8) ADS-B for Surveillance in Non-Radar Airspace		
9) ADS-B Separations Standards		

Enhancements 5, 8, and 9 will be analyzed in Phase 2. Other metrics such as incidents or number of flight initiatives may be addressed qualitatively during the Phase 2 analysis.

4.1.2 Limited Deployment versus NAS-wide

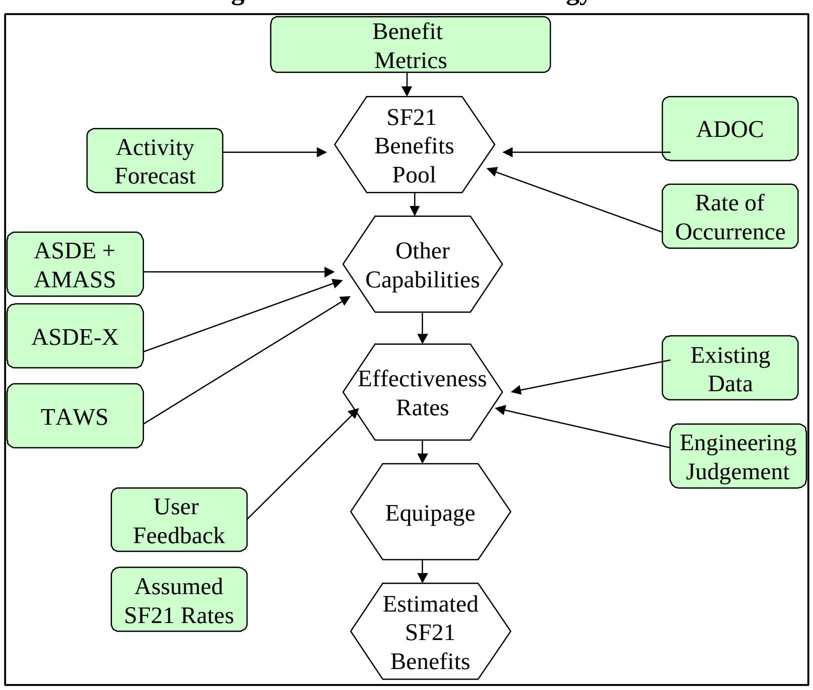
The Phase 1 analysis focused on the LD in the ORV and Alaska Capstone. However, it was recognized that an analysis of operational benefits at the NAS-wide level eventually would be required as input for the link technology selection decision. Additionally, the scope of the Safe Flight 21 LD decision is not established firmly at this point in time, and also may include other "pockets" of implementation where the ADS-B technology appears to be cost beneficial. Establishing a preliminary NAS-wide model for estimating benefits was a worthwhile effort in

Phase I. The team used range estimates as a first step to describe NAS-wide benefits that might be achieved. These estimates have a very high range of uncertainty and require further analysis in the future.

4.2 Benefit Baseline and Interdependencies

The Safe Flight 21 benefits were estimated relative to the existing ATC system, with established ATC procedures currently in effect. This reference point was modified to reflect any approved future enhancements that become effective during the Phase 1 analysis. For example, if Free Flight Phase I tools like Center-TRACON Automation System (CTAS) are implemented at selected terminal areas, the benefits of Enhancement 3 (Improved Terminal Operations in Low Visibility) should be measured as incremental benefits after CTAS is installed in the system. In the case of Enhancement 2 (Cost-Effective CFIT Avoidance) estimates reflect the incremental benefits after the recently mandated Terrain Alert and Warning System (TAWS) becomes effective. This methodology assures that benefits that already have been claimed by other FAA programs are not double counted. Figure 4-1 describes the methodology used by the subteam.

Figure 4-1. Benefits Methodology



Increased demand and future growth in the number of aircraft operations served by the airspace system were developed for the 10-year period of analysis by applying the FAA Terminal Area Forecast (TAF) and projected growth in aircraft fleet size. Benefit outcome metrics, such as the number of future CFIT related accidents were estimated to establish a “benefits pool” for the Phase 1 analysis. This was adjusted to reflect benefits of existing and planned improvements as described above. The effectiveness of a Safe Flight 21 enhancement was then applied to the remaining benefit pool considering the rate of user equipage.

After careful evaluation, the Safe Flight 21 benefits team determined that Improved Terminal Operations and Airport Surface Display to the Controller (Enhancements 3 and 7) have inherent interdependencies in the terminal and surface areas. In addition, the team also found that Surface/Approach Operations and Airport Surface Display to the Controller (Enhancements 6 and 7) have common safety relationships in the terminal area. As a result, the logical merger of the above enhancements was proposed to the Safe Flight 21 Select Committee to avoid double counting overlapping benefits. The committee approved the combined benefits analysis of Enhancements 3 and 7 (efficiency), and 6 and 7 (safety) based on the information provided by the team.

The interdependency of Enhancements 3 and 7 is due to the impact of reduced inter-arrival and departure spacing on overall airport capacity, which in turn impacts surface movement in the terminal area. The efficiency benefits for Enhancements 3and 7 are translated then into delay savings. For more details, refer to Volume 1, Appendix A.

The interdependency of Enhancements 6 and 7 is due to the interaction of both controllers and pilots during movement in the surface area. The safety benefits for Enhancements 6 and 7 are based largely on the Runway Incursion program findings of the total benefits pool. For more details, refer to Volume 1, Appendix A.

4.2.1 Safety

Safety benefits are derived from estimated reduction in accident rates and the potential cost savings in terms of avoided loss of life, injuries, aircraft losses, and aircraft repairs.

Safety benefits for the state of Alaska for Enhancements 1, 2, and 4 were estimated based on detailed accident data review for weather related, CFIT, and midair accidents. The main source of information is the National Transportation Safety Board (NTSB). Volume 2 of this report contains detailed information on data review for Enhancements 1, 2, and 4.

The Runway Incursion Reduction Program (RIRP) Analysis Team completed a thorough assessment of runway accidents in the NAS. Based on the site-by-site findings of their work, safety benefits were estimated for Enhancements 6 and 7 in the ORV. In addition, the Safe Flight 21 benefits team completed an assessment of surface accidents not included in the scope of the Runway Incursion program. These accidents occurred on the surface of the airport off the runway and involved at least one aircraft not landing (e.g., taxing).

The cost of avoided accidents was quantified using monetary values for avoided fatalities, avoided injuries, replacement costs of destroyed aircraft, and restoration cost of damaged aircraft. These values are documented in the *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs* published by the FAA's Office of Policy and Plans (APO).

4.2.2 Efficiency

Efficiency benefits are defined as a quantitative measurement of more efficient operations in the enroute, terminal, or surface domains. The FAA's definition of efficiency has been associated with system flexibility, user access, and system delays. In the Phase 1 analysis, efficiency benefits primarily refer to the quantification of delay savings. The Phase 2 analysis is expected to address efficiency benefits associated with system flexibility and user access.

Minutes of delay savings were estimated and then quantified using monetary values for reduction in fuel, crew, and maintenance cost savings as defined in the *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs* published by APO. Efficiency benefits for Enhancements 3, 6, and 7 in the ORV are documented as part of this report and do not include passenger value of time (PVT) savings.

4.2.3 Effectiveness

From the perspective of the benefits analysis, effectiveness rates are defined as the measurable improvement of a given technology in the operational environment. This rate describes the marginal improvement over the current baseline that could be obtained in the enroute, terminal, or surface domains.

The estimate of effectiveness rates for the Safe Flight 21 enabling technologies were developed based on the team's research of published materials and inputs from users and the FAA. Due to limited data, these rates are based largely on engineering and operational judgement.

The estimated effectiveness rates used to calculate potential safety and efficiency benefits from Safe Flight 21 are subject to improvement and will be revised as new information from the operational sites at ORV and Alaska Capstone becomes available. For more detailed information about assumed effectiveness rates by enhancement, refer to Volume 1, Appendix A.

4.2.4 Summary of Benefits by Enhancement

Table 4-2 presents a summary of Phase 1 benefits for LD in constant year 2000 $M. The table shows combined totals by enhancement. Enhancements 1, 2, and 4 are related to safety benefits in Alaska Capstone; Enhancements 3, 6, and 7 are related primarily to efficiency benefits in the ORV.

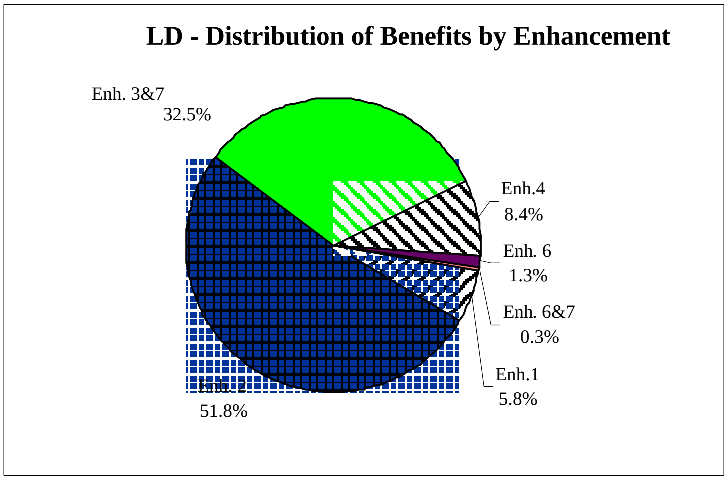
Table 4-2. Summary of Benefits for FY02-FY11 (Constant $M)

SF21 Enhancements	Safety Totals		Efficiency Totals	
	LD	NAS-Wide	LD	NAS-Wide
1) Flight Information Services - Broadcast (FIS-B)	$33	$551	-	-
2) Controlled Flight into Terrain (CFIT)	$297	$1,183	-	-
3) Low Visibility Terminal Operations (LVTO) & 7) Airport Surface Display for Controller	-	-	$186	$900-$1,600
4) Enhanced See and Avoid (ESA)	$48	$346	-	-
6) Surface/Approach Operations (S/AO)	-	-	$7	$337
6) Surface/Approach Operations (S/AO) & 7) Airport Surface Display for Controller	$1	$85	-	-
Total	$380	$2,165	$194	$1,237-$1,937

Note: Detail may not add to total due to rounding.

Figure 4-2 illustrates the split of the LD aggregate benefits total among the Safe Flight 21 enhancements.

Figure 4-2. LD Distribution of Benefits by Enhancement



For the ORV, it is assumed that efficiency benefits derived from ADS-B technology available to the controller and the pilot will reduce inter-arrival/departure spacing (during instrument meteorological conditions (IMC) and visual meteorological conditions (VMC)), increase capacity, and improve surface movement in the terminal area. In addition, the stream of benefits is based on the assumption that three cargo airlines (UPS, FedEx, and Airborne Express) will equip aircraft with ADS-B at Memphis, Louisville, and Wilmington. It is also assumed that Northwest Airlines aircraft operating at Memphis will be equipped with ADS-B during the ten-year analysis timeframe. This assumption has a major impact on efficiency benefits for Enhancement 3 and 7.

For Alaska, it is assumed that safety benefits derived from ADS-B, low-cost CFIT avoidance, and FIS-B technology available to the pilot will reduce the accident rate for Part 91 and 135 aircraft. These benefits are derived from providing improved weather information to the cockpit, and increased terrain situational awareness through cost-effective CFIT, and enhanced see and avoid (Enhancements 1, 2, and 4). In addition, the benefits are based on the assumption that over the ten-year life cycle, 55% of general aviation aircraft operating in Alaska will voluntarily equip with the Capstone avionics.

5.0 ECONOMIC ANALYSIS

5.1 Economic Analysis Results

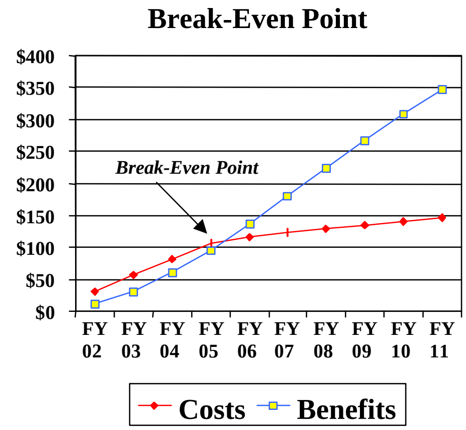
The economic analysis considered the following criteria: FAA life cycle costs, user benefits, NPV, and B/C ratio. **The analysis did not include user avionics costs, PVT, or user business case benefits.** The results shown below in Figure 5-1 are based on the most likely cost and benefit estimates, and summarize the results of the Safe Flight 21 LD economic analysis.

Figure 5-1. Results of the Safe Flight 21 LD Economic Analysis

$PVM

	ORV	AK	LD
Cost	$39	$107	$146
Benefits	$114	$234	$348
NPV	$75	$127	$202
BC	2.9	2.2	2.4

Major Drivers:
- Efficiency in Ohio River Valley
- Safety in Alaska (Statewide)



Basis:

- Analytical timeframe: FY02-FY11 (10 years).
- FY 2002 and prior costs are considered sunk.
- A 2% inflation rate was used, per the Office of Management and Budget (OMB) inflation guideline of February 2000.
- The discount rate of 7% was used for the ten-year period, per OMB Circular No. A-94, Appendix C, as revised February 2000.
- All NPV and B/C ratio calculations were performed in present value dollars.

The results of the Phase 1 analysis show that the LD initiatives are cost beneficial and that the combination of the ORV and Alaska are expected to equal cumulative benefits at the end of FY05.

5.2 Risk Analysis and Uncertainty

5.2.1 Risk

For the purpose of this analysis, risk is defined as the probability of an undesirable event occurring and the consequences of that occurrence. In the context of this analysis, risk is the probability that the Safe Flight 21 program will fail to deliver the benefits projected, either in whole or in part, and the consequences of this failure. Risk also is expressed as the uncertainty of cost and benefit estimates, which are influenced by elements such as system effectiveness, change of scope, change of schedule, unforeseen costs, or the degree of stakeholder participation.

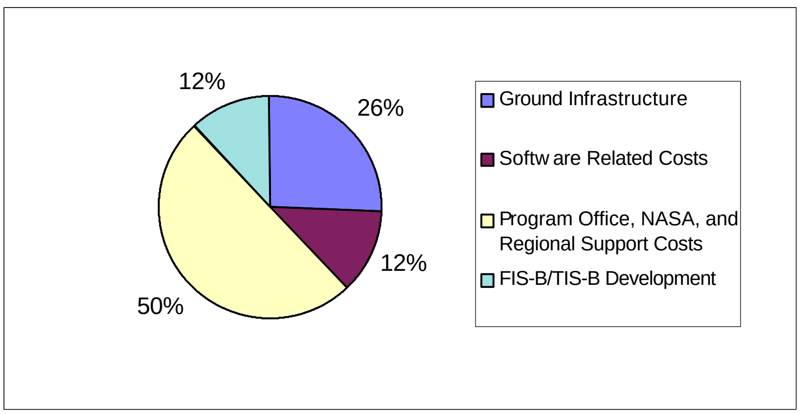
The ROM cost and benefit estimates of Phase 1 are based on current technical and operational requirements for LD submitted by the Integrated Product Team (IPT). Due to the ongoing efforts to delineate Safe Flight 21 requirements, a full sensitivity analysis was considered to be premature at this stage. Under Phase 2 of this effort, the team will examine how the possible ranges of cost and benefit drivers will impact the range of economic analysis results.

5.2.2 Key Cost Drivers

Figures 5-2 and 5-3 show ORV and Alaska F&E costs by WBS as a percentage of the overall estimate. The WBS elements with the highest percentage are classified as cost drivers. Once cost drivers are established, the IA team can ensure requirements have been defined properly and quantified for those activities that have the greatest impact on program funding. Also, risk surrounding these cost elements can be assessed and incorporated into the analysis.

Program office, NASA, and regional support costs are the primary cost drivers in the ORV (see Figure 5-2). These personnel provide the support infrastructure to continue ongoing development, test, operational evaluations, and fielding of Safe Flight 21 initiatives. Team composition, roles, and responsibilities have been defined for the duration of the program, thus minimal risk is associated with this element. The remaining cost share is split between ground infrastructure, FIS-B/TIS-B, and software. These elements are not among the leading cost drivers, yet inherently are more risky due to the nature of the effort. The unit cost for the ADS-B ground stations have a significant impact on overall ground infrastructure costs. The development costs of FIS-B, TIS-B, and automation/avionics software may vary depending on operational evaluation activities.

Figure 5-2. Ohio River Valley F&E and O&M Cost Drivers



Ground-broadcast transceivers and AWOS are the primary cost drivers in the Alaska estimate (see Figure 5-3). Safe Flight 21 cost estimates for LD in Alaska included a significant expansion in scope for the Capstone initiative (Bethel area) to include statewide coverage for Alaska. The impact of the expanded scope is shown in an increase in buy quantities for GBTs, multiprocessors, LAAS, AWOS, and vehicle ADS-B. Any modification to the coverage area of the Capstone program will have a significant impact on the total program cost.

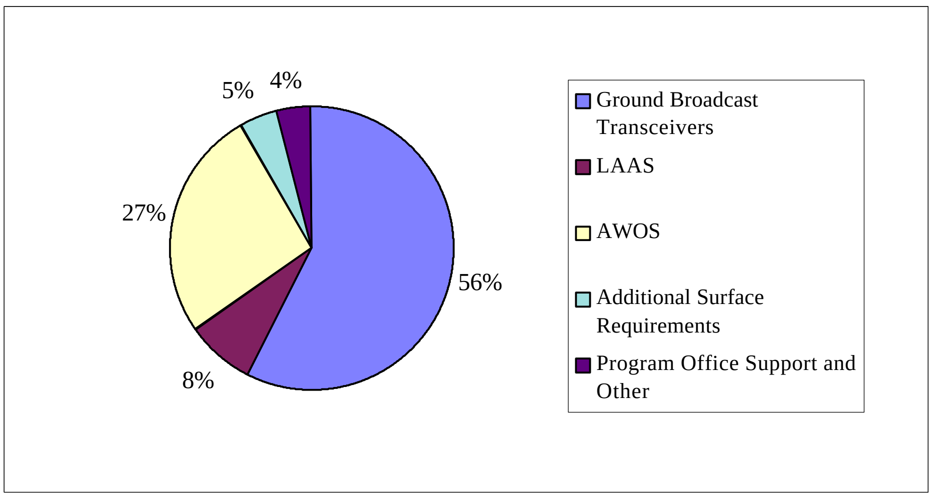
Due to the lack of telephone lines in most of Alaska, telecommunications services for the GBTs and AWOS systems must be performed via leased satellite bandwidth. Sites that are eligible will use the FAA's Alaskan NAS Interfacility Communications System (ANICS). However, the majority of sites will need to lease bandwidth from more expensive commercial vendors. These recurring telecommunications charges account for approximately 50% of the total cost for both the GBT and AWOS systems.

The unit cost for the GBTs also has a significant impact on overall ground infrastructure costs. Equipment costs for the 188 GBT systems included in the estimate amounted to approximately 16% of the total GBT costs.

The AWOS systems will need to be installed approximately 1,000 feet off the runway to avoid being a collision hazard. Gravel pad and road construction is necessary for proper installation and access to each system. Non-recurring telecommunications and utility setup costs are also incurred during installation. In total, installation activities account for approximately 25% of total AWOS system costs.

During Phase 2 of this analysis, risk analysis will be performed on NAS-wide implementation activities.

Figure 5-3. Alaska F&E and O&M Cost Drivers



5.2.3 Key Benefit Drivers

The Safe Flight 21 LD ROM benefit estimates identified three key benefit drivers: effectiveness rates, voluntary equipage, and rate of occurrence.

5.2.4 Effectiveness

Effectiveness rates are related directly to the performance of a given technology in the operational setting. At this point, the assumed rates used to project LD benefits are based on available data, and engineering and operational judgement for each of the six enhancements analyzed. These assumed rates are point estimates, and need to be refined in the near future to include new information from real-operational demonstrations, or simulation efforts.

The potential impact of changes on effectiveness-rate assumptions could have a significant impact on benefit estimates.

5.2.5 Equipage

Voluntary user equipage is an essential input to the projection of Safe Flight 21 benefits. The Safe Flight 21 cost benefit team developed expected equipage rates for LD and NAS-wide implementation. These rates are largely based on team consensus regarding the timeframe for user equipage. Beginning and ending years are used as a proxy to project linear equipage rates per user class.

For LD, user avionics buy quantities provided by cargo airlines were used to estimate user avionics costs and associated equipage rate. To capture the equipage rates of Northwest Airlines, it was assumed that the number of aircraft expected to equip with ADS-B technology would follow the number and the rate of FedEx at Memphis.

For NAS-wide implementation, sources such as the 1999 Aviation Almanac, and APO Aviation Forecast for 2000-2015 were used to obtain a valid count and forecast of total aircraft per user class. From this starting point, discussions among the members of the cost benefit subgroup resulted in expected timeframes for user class equipage. For simplicity, a linear equipage rate was assumed based on the agreed upon beginning and end dates. Table 5-1 below summarizes the assumed equipage rates.

Table 5-1. LD and NAS-wide Equipage Rates

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Limited Deployment										
Capstone	13%	24%	35%	45%	56%	57%	57%	57%	57%	57%
Ohio River Valley (Cargo only)	34%	58%	77%	88%	100%	100%	100%	100%	100%	100%
Ohio River Valley (Cargo & NWA)	24%	48%	69%	84%	100%	100%	100%	100%	100%	100%
NAS-Wide Implementation (For ADS-B)										
Commercial	1%	17%	33%	50%	67%	83%	100%	100%	100%	100%
Air-Taxi	1%	13%	25%	38%	50%	63%	75%	88%	100%	100%
General Aviation	3%	7%	14%	22%	29%	35%	41%	47%	53%	59%

The risk associated with assumptions on equipage rates is that users may choose not to equip at the projected levels. This risk is dependent largely on user preferences, avionics costs, and the area of coverage where Safe Flight 21 enabling technologies would be available.

5.2.6 Rate of Occurrence

The rate of occurrence is related to the variables used to derive important forecast rates or projections such as number of accidents per 100,000 flights and the number of future operations. These derived rates were used to calculate potential cost savings in terms of avoided accidents (safety), or reduced aircraft operating costs (efficiency).

These key drivers are not completely independent from one another, and are subject to external influences such as cost of avionics or user preferences that are outside the control of the FAA.

For further insights about the assumed effectiveness rates, equipage rates or rates of occurrence, refer to Volume 2 of this report.

6.0 COMPARISON OF REQUIRED VERSUS CIP FUNDING

The FAA budget process requires that the agency prioritize its programs to allocate budget submissions on these priorities In March 2000, the Safe Flight 21 program office briefed the SAT in preparation for the FY02-FY06 CIP budget process as well as the upcoming Joint Resources Council (JRC) decision on the FAA FY02 budget. Cost estimates developed for this analysis were used as the basis for the requested funding profile. These estimates included all requirements in ORV and expanded scope of the Capstone implementation, leading to statewide coverage in Alaska. These estimates exceed the CIP funding levels by the amounts shown in Table 6-1.

Table 6-1. FAA CIP vs. Required F&E Funding
(FY02-FY06, Current Year $K)

	FY02	FY03	FY04	FY05	FY06	TOTAL
ORV						
CIP	$10,000	$10,000	$10,000	$9,700	$3,000	$42,700
Required	$14,816	$11,415	$10,275	$9,741	$3,449	$49,696
Delta	-$4,816	-$1,415	-$275	-$41	-$449	-$ 6,996
Capstone						
CIP	$15,000	$10,000	$5,000	$ 5,300	$2,000	$37,300
Required	$21,097	$20,504	$21,080	$19,386	$3,055	$85,121
Delta	-$6,097	-$10,504	-$16,080	-$14,086	-$1,055	-$47,821

The difference between required funding and the CIP funding levels prompted a trade-off analysis to estimate the economic impact on LD, assuming Safe Flight 21 funding might be limited to the CIP levels.

The CIP funding levels for ORV is approximately $7M short of the required funding over the implementation period. This shortfall primarily impacts non-recurring development efforts, as well as Program Office and Regional/Tech Center Support. It is important to point out that the ORV initiatives are R&D in nature and funding them at required levels has significant value in overall ADS-B risk reduction and cost avoidance for future NAS-wide implementation.

The CIP funding levels for Capstone contrast with the statewide scope envisioned at the required funding level. A reduction in the program scope to the funding level has a significant impact on the amount of coverage in Alaska based on fewer GBTs, multiprocessors, LAAS, AWOS, and vehicle ADS-B. This reduced coverage is likely to have a significant reduction in voluntary user avionics equipage, with a corresponding decrease in benefits.

7.0 CONCLUSION

This initial ROM cost benefit analysis indicates that the Safe Flight 21 LD is cost beneficial. However, this analysis is a partial look at this time for the three reasons:

- User costs for avionics equipage and the user business case for benefits were not included in the economic analysis. These are major cost and benefit drivers and should be added during the Phase 2 analysis.

- Benefit estimates include only six of the nine Safe Flight 21 enhancements, and some of the applications within each enhancement were not included in this phase of analysis. Effectiveness of many of these enhancements is still uncertain, and remains to be validated during future operational evaluations.
- Only a subset of benefit outcome metrics was included. Many other metrics remain to be quantified during the Phase 2 analysis.

Proceeding with the Safe Flight 21 program should provide risk mitigation and reduction for subsequent NAS-wide implementation of these technologies. This is a significant benefit that is not captured in the economic indicators. There is a considerable range of uncertainty in these preliminary estimates of costs and of benefits. The additional data gained from operational evaluation and from further analysis in Phase 2 will help to reduce this uncertainty.

8.0 NEXT STEPS

The Phase 1 analysis provided an initial estimate for budget planning purposes, and resulted in an excellent structure for a more detailed analysis during Phase 2. As indicated above, there are additional enhancements and metrics to be evaluated prior to the Safe Flight 21 investment decision in September 2001. The Phase 2 analysis should concentrate on the following tasks:

- Develop a user business case.
- Include additional benefit outcome metrics and applications that were not evaluated in Phase I.
- Reduce the range of uncertainty in effectiveness assumptions in close coordination with Operational Evaluation 2 at Louisville, Operational Evaluation 3 at Memphis, and aviation industry in Alaska. Validate and refine assumptions on user equipage and system effectiveness.
- Expand the analysis to estimate NAS-wide costs and benefits, and identify other "pockets" of implementation that could prove cost beneficial (December 2000).
- Develop input on cost effectiveness of the link technologies for the Link Decision (June 2001).
- Prepare data sources, references, and models for the Safe Flight 21 Investment Analysis kick-off (spring 2001).

APPENDIX B

CONTRIBUTORS

A large number of people and organizations contributed to this report and are engaged in the ongoing effort. Please see below for a listing of the organizations and individuals that are team members and supporting members.

Organizations supporting this analysis are as follows:

FAA: AND, ASD, ATO, ATP, and AFS
Industry: UPS, AOPA, VOLPE, CAASD, Marconi/TAC, MCR Federal, and SETA

Individuals that are team members and supporting members are as follows:

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